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UTILIZATION OF SOLAR ENERGY

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4. Refer to [3]. I expressed this viewpoint recently in my lecture "On the utilization of solar energy" given at the symposium called "The present and future of the energy question -- A symposium concerning new forms of energy and savings of energy (June 14, 1973)," jointly sponsored by the Special Committee on Industry and Popular Livelihood of the Science Council of Japan (Chairman, Yōichirō Mashiko) and the Safety Engineering, Research and Construction Committee. I understand that the contents of the lectures given on that day are scheduled to be published in a book form. An outline of the lecture was reported in Kagaku Shimbun [Science Newspaper], June 22, 1973 issue.

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This article may have been written in excessively subdued terms. If the reader is given a pessimistic impression as a result, such was not the intention of the writer. We researchers studying the utilization of solar energy may on the one hand constantly cherish vast dreams, but we must stride forward with our feet on the ground, and each step we take must be certain and reliable. I think that our many predecessors have done precisely this during the long history thus far. I have written this article in this way in order to help the reader understand this.

batteries and other structural contrivances, advances in the theory of physical properties of semiconductors and in materials, and advances in manufacturing techniques?

The efficiency of solar batteries is not their only desirable feature. Other desirable points are their stability, which is attributable to the fact that they are solids, and the fact that only a surface layer of several micrometers is sufficient from the functional standpoint. In connection with the latter point, solar batteries in sheet (thin film) form are entirely conceivable.

The processes which occur in the PN junctions of semiconductors are, of course, quantum processes. However, there is another important quantum process, the photochemical process. It is precisely this process, operating as photosynthesis in plants, which has been supporting life on Earth for hundreds of millions of years in the past. That is, it is it which is currently converting rays of sunlight into chemical energy on the most immense scale.

I intend to discuss elsewhere the conversion of solar energy into chemical energy [7], and I have now almost reached the limit of the space scheduled for this article. Consequently, I will omit the details here. However, the final goal of researchers studying the utilization of solar energy is to decompose water, which is abundantly available, for example by means of the photochemical action of rays of sunlight, to extract hydrogen, and to use it as a fuel, or else to use it as a secondary energy source via the medium of hydrogen-oxygen fuel cells. It is their hope to solve in this way the entire problem of energy and resources. This would be possible even today if solar batteries were used, but unfortunately it cannot be said to be practical.

impetus ought to be given to research in photoelectrical transformations in the broad sense. The solar battery is something which everyone knows about in this area. The successes achieved here are nothing but the achievements of advanced research concerning the physical properties of semiconductors. In April 1954, the specialists at the Bell Telephone Laboratory announced solar batteries using PN junctions of silicon with an energy conversion efficiency of 6%. After that time, solar batteries were put into actual application in a certain sense. Even those currently available on the market have now improved their performance properties until they have an efficiency of approximately 11%. Naturally, they are inevitable costly because they are made from single crystals with a high degree of purity, and it is said that, if one were to use solar batteries to generate electricity on the Earth, the cost would be about ¥30,000-¥40,000 per watt, including the costs of the storage battery equipment as well. Under these conditions, solar power stations are not economically feasible now. However, one may say that they have already entered the realm of practical application in fields where cost does not matter, for instance as power sources for space rockets, unmanned lighthouses, or radio relaying stations.

Last year, the delightful news was announced that IBM specialists had succeeded in manufacturing solar batteries with a conversion efficiency of 18% using chiefly potassium arsenide [6]. The work is still at the laboratory level. There probably would still be many problems if it were put into mass production, but at any rate this is delightful news. At the Paris conference, the prediction was made that the efficiency of solar batteries would reach 20% within a few years from now.

An efficiency of 20% is quite a good efficiency. However, this is still much lower than the efficiency which is attainable theoretically. May we not expect even further improvements in the efficiency thanks to the development of laminated solar this approach is the most practical method suitable for a transition period such as the present.

Now the time has come to discuss the utilization of solar energy as light. As was already mentioned, utilization as light is superior in principle (from the standpoint of physics) to methods of using it as heat. One may also say that it is more difficult as a result. This difficulty is closely connected with the high entropy, which was already mentioned.

In order to utilize the energy of light, it is necessary to convert it into some other type of energy, except in cases when the light is to be used as light (for example, use for daylight illumination, as in the table). Mr. Hidetoshi Takahashi once pointed out an important thing concerning the conversion of light energy [5]. He said that the conversion of light energy into another type of energy can be characterized as a "quantum conversion." When other types of energy are converted, this assumes the form of conversions of the physical macroscopic parameters. However, in the case of light, he says, the process of conversion is strictly a quantum process which is not mediated by any macroscopic parameters. This is an extremely important point in the utilization of solar energy.

This is so because quantum processes belong generally to the region of modern physics, which is a branch of sciences which is still developing at the present time. For this reason, we can still have hope for the future. At the same time, we must know /663 that the future of the utilization of solar energy will be governed by the state of development of purely scientific research, and that even at the present time, research in the utilization of solar energy is not simply applied research.

It is desirable to convert light into the electrical energy which has the highest possible value. Consequently, primary clean atmosphere, and in certain respects this cannot be called utilization of solar energy itself. In France, which has the world's largest solar furnace, research is being done concerning the use of these high temperatures to fix the nitrogen in the air or to decompose steam. If this research is successful, it will mean success in the utilization of energy.

Thus, we can see that the utilization of solar energy as heat, generally speaking, has gradually been put into actual application from the low temperatures towards the high temperatures. At the present time, we have reached the stage of putting solar water heaters into actual application, and I expect that the next move will be towards putting solar heating into practical application. In actual fact, this tendency has already manifested itself. There have been more and more studies and papers about solar heating, and it was possible to sense this also at the Paris conference.

Here let us once again turn our thoughts to the total picture of utilization of solar energy. As I already mentioned, it is not desirable to transform it into the form of heat except in cases where the utilization of heat is the final form of energy. In particular, when it has been converted into low-temperature heat, it becomes impossible to convert it efficiently into another form of energy.

The use of solar energy as heat naturally has great significance. However, its greatest significance is the fact that it makes it possible to economize the other sources of energy and to reduce environmental pollution. In this sense, it ought to be promoted more and more in the future. Rather than thinking merely interms of solar heat alone, one ought to explore combinations with fossil fuels and incorporate methods of automatic controls which have developed recently in order move towards reductions of the consumption of fossil fuels. One may say that of a thermal engine using fuels except for the fact that this steel pipe plays the role of the boiler in an ordinary thermal engine. The thermal efficiency of solar engines of this type is approximately 15%.

As is clear from the table, many of the items listed under utilization as heat, especially those at low temperatures, have already been put into actual operation. Among the uses at low temperatures, almost all of those in the top half of the list are already in use at the present time and are providing many benefits. (One exception would be the use of sunlight for manufacturing salt, which has been replaced by the method using ion-exchange resin diaphragms).

Thus, the fact that these uses of sunlight as low-temperature heat have been successful is based on the properties of the solar energy itself, especially its high dilution and its high entropy, which we have already mentioned. It is only natural that this should be so.

Solar water heaters have already been placed on sale on the market, and in Japan more than 2 million of them have gone into use. Thus, one may say that they have already entered the stage of actual applications. Some readers may find it strange that I have included solar air-conditioning among the high-temperature uses. However, in order to use solar heat for cooling purposes, one must either heat an absorption type refrigerating machine (one which has the same principles of operation as those used in a gas refrigerator) or operate an ordinary refrigerating machine with a solar engine. In either case, high temperatures are necessary. (Of course, other methods are possible. For instance, one can generate electricity by means of solar batteries and operate the refrigerating machine with this electric power.) Solar furnaces are already being used in actual applications, but this is because they can obtain high temperatures (3000-3500°C) easily and in a lid (double lids are considered to be desirable). It utilizes the hothouse effect (since glass admits incoming visible rays but interrupts heat rays going out from the inside, the temperature on the inside will rise).

For utilization at high temperatures, it will be necessary to have condensing devices using lenses or concave mirrors as well as tracking devices which keep the former devices pointing constantly towards the Sun. Here the problem suddenly becomes a difficult one, because when rays of sunlight are utilized on a large area, much attention comes to be focused on the question of /662 materials, and consequently on the question of cost. The rays of sunlight themsleves are free, but the equipment to utilize them costs something, and the balance between these two elements governs whether the utilization of solar energy is practical or not. In actual fact, there are even some researchers who believe that any type of equipment which requires tracking devices cannot be used practically as equipment utilizing solar energy. My own opinion is not as extreme as this. It believe that there is still room for research in simple, inexpensive tracking devices which would not require the entire equipment as a whole to be moved.

In the table, the items listed in the column for "utilization as heat" are arranged more or less according to the temperature, from the lower towards the higher temperatures. The efficiency also declines more or less in this sequence. For example, the efficiency of solar heat distilling apparatus differs depending on the type of the apparatus but goes as high as 60-70%. The efficiency of solar water heaters is about 50% in those with an area of about 2 m^2, consisting of several cylindrical containers lined up in a row, which are frequently seen in Japan. There are also various types of solar engines. A steel pipe is passed through the caustic curve part of a parabolic mirror, and a special liquid (for example, diphenyl chloride) inside this pipe is heated. In other words, the principle is exactly the same as that

TABLE 1. FORMS OF UTILIZATION OF SOLAR ENERGY

Utilization as heat	Utilization at low temperatures (100°C or less)	Promoting melting of snow Use of sunlight for manufacturing salt Vinyl chemicals Hothouses Drying Distillation of water Solar water heaters Solar heating
	Utilization at high temperatures (more than 100°C)	Solar heat rice cookers Solar engines Solar air-conditioning Solar furnaces
Utilization as light		Daylight illumination Solar batteries Photochemical reactions

Consequently, utilization as heat is not inferior to utilization as light. The utilization of solar energy is often referred to commonly as "utilization of solar heat." This indicates that thermal utilization may be regarded as being more successful.

Let us use the boiling point of water as the dividing line in our discussion of utilization as heat. It is convenient to consider the temperatures below this as utilization at low temperatures, and to consider the higher temperatures separately as utilization at high temperatures. The former temperatures are those which can be attained comparatively easily with simple, stationary type equipment, such as flat plate heat collectors or hot boxes. A hot box is a box painted black on the inside which has a glass wavelength of about 2.5 μm. Expressed in terms of music, this would equal more than three octaves. One can gather that it would be no simple matter to devise equipment capable of efficient conversion for any wavelength within such a broad range.

In the preceding I have described the three essential factors which make it difficult to utilize solar energy. It is entirely because of these difficulties that, even though research in the direct utilization of solar energy has a history of more than 200 years, in almost every case it has not yet entered the stage of actual application. Today when public attention has shifted towards solar energy, if I wanted to I would be capable of writing any amount of encouraging things about it, but it seems to me that this would not really be conscientious on my part. Therefore, I have begun by speaking seriously of the difficulties in order to enable the reader to understand the essence of the matter.

Current Status and Future

One must remember clearly that research on the utilization of solar energy has been precisely a struggle with these three difficulties. In Table 1 I have summarized the various forms of utilization of solar energy which are currently being practiced or studied. Let me now give some explanation of this table.

The utilization of solar energy can be divided up into two main types: utilization in the form of light or after converting the light directly into another type of energy, and utilization after converting it into the form of heat. It said above that heat is the lowest form of energy. This is true only from the viewpoint of physics and thermodynamics, but it does not necessarily apply from the engineering standpoint, which considers mainly the final form of energy utilization. Needless to say, heat is the highest form of energy for us when we want heat, for example, when we want to warm up when we are very cold.

only partially possible. This fact indicates that heat is the final form of energy and is, so to speak, the least valuable type of energy.

The values of the other types of energy besides heat can also be compared on this basis. Let us suppose that we have two types of energy, A and B. If A can be converted relatively easily into B but the opposite conversion cannot be made as easily, A will be an energy with a higher value than B.

In this sense, electrical energy flowing through a conductor is probably the highest quality of energy. On the other hand, energy in the form of electromagnetic waves tends to be converted easily into heat and cannot be called good-quality energy. This is especially true of electromagnetic waves with long wavelengths. They will turn into heat after merely being absorbed into matter, and it is not easy to convert them into energy other than heat, and especially to convert them with a high efficiency.

Although the term "high entropy" is a word coined by the writer, I will have to use it because I can hardly find any other term to express properties of this type. Specialists are familiar, at least intuitively, with these properties of rays of sunlight, but it is not easy to explain it to ordinary readers who are not specialists. However, I will have attained my purposes if the reader is able to grasp a vague sense of this sort of difficulty from this explanation.

The high entropy also includes the fact that the rays of sunlight do not have a uniform wavelength. If rays of sunlight were electromagnetic waves consisting of a single wavelength -- that is, if they were monochromatic light -- it would have been much easier to utilize them. Unfortunately, the wavelengths of rays of sunlight have a broad distribution ranging from ultraviolet rays with a wavelength of about 0.3 μm to infrared rays with a sunny weather, it will be necessary to store up at all times energy equivalent to:

$$36 \text{ kWh} \times 3/4 \times 10 = 270 \text{ kWh} \doteq 240{,}000 \text{ kcal}$$

However, it is no exaggeration to say that at the present time there is no method for efficiently storing up large amounts of energy. It is entirely impossible to store it up in the form of light rays, and extremely large amounts of matter will be necessary if we are to store it up in the form of heat. Various types of heat storing materials are being considered, but they must fulfill certain conditions. That is, they must be present in large quantities, they must be cheap, and they must have no toxicity. Furthermore, heat is a form of energy which escapes very easily.

It would be most desirable to store it up in the form of electrical energy. However, storage batteries are quite heavy and store up only small amounts of electricity (a storage battery weighing about 40 kg is necessary to store up 1 kWh of electricity). For this reason, the question of energy storage is indissolubly connected with the utilization of solar energy, and the cause of this is based on the intermittent nature of solar energy.

(3) High Entropy

This is the most difficult to explain, but at the same time it is the most essential item expressing the difficulties of utilizing solar energy. According to the Second Law of Thermodynamics, once energy has been converted into heat, it is impossible to convert it 100% into another type of energy. All types /661 of energy can be converted easily into the form of heat, but once they have turned into heat it is not an easy matter to convert them into some other form of energy, and such a conversion is

(2) Intermittent Nature

One of the qualifications for a modern energy source is that it must be constant. That is, it must be able to supply energy at a constant rate at all times, regardless of the time of day or the season of the year. However, solar energy has fluctuations depending on the time (day and night), fluctuations depending on the season (summery and winter), and fluctuations depending on the weather (sunny and cloudy). Thus, in its present form it cannot be a modern energy source.

Thus, it is necessary to combine it with equipment which will accumulate the energy in some way or another and which will enable it to satisfy the requirement of constancy as an energy source, by storing up the energy when conditions are advantageous (summer, daytime, sunny weather) and releasing the stored energy when conditions are disadvantageous (nighttime, cloudy weather, winter). For this purpose, it is necessary to store up large amounts of energy by some method or another. Even if we give up, for the time being, the idea of storing up summer sunlight until the winter, when we recall that cloudy weather sometimes lasts for as long as periods of 10 days, it will be necessary to store up very large amounts of energy.

For example, let us suppose that 3 kW is the amount of electric power necessary (constantly) for taking care of one dwelling by means of the electricity generated from rays of sunlight. This amounts to 72 kWh per day. If the time band which can be utilized for generation is 6 hours per day, it will be necessary to generate 38 kWh during the daytime in order to provide for the nighttime. Since 1 kWh is 860 kcal, it will be necessary to store up about 30,000 kcal of energy in some form or another. If we consider that cloudy weather may continue for as long as 10 days, and if we suppose that the amount of electricity generated during cloudy weather is about one-fourth the amount generated during directly facing the sun (that is, at right angles to the rays of sunlight) during the daytime on a very clear day.

Rather than this, I propose that we think of the total amount of solar energy coming to the Earth divided by the total surface area of the globe, which is 5.1×10^{14} m^2. In this case, the figure will be no more than about 160 W per m^2. However, this figure may be considered to be the amount of solar energy received by the horizontal plane of the Earth's surface averaged out for day and night, summer and winter, clear and cloudy weather, and tropics and frigid zones. Such a figure is quite suitable as the basis on which to consider the utilization of solar energy. This is so because it is a quite suitable figure for those cases in which stationary type equipment, which ought to be the chief type of equipment used when utilizing solar energy, as well be mentioned later, especially large-area equipment which is unable to track the Sun, is to be used all year round in one place. The number is only about one-sixth of that in cases when the direct rays of the Sun are received on a surface perpendicular to them.

Energy of 160 W/m^2 is quite diluted energy. However, it is only natural that this should be so, for if this number were any greater the globe would turn into a fiery inferno. On the other hand, it presents technically difficult problems when the Sun is to be used as a source of energy. If there were a method of converting 10% of the solar energy reliably into electric power, the equipment necessary for generating 10,000,000 kW of electricity would have a large area amounting to:

$$100 \times 10^6 \times 10^3 \div 160 \fallingdotseq 6 \times 10^8\ m^2 = 600\ km^2$$

Since I will return to this question once again later on, I shall not go into it further here.

(1) High Dilution

The total amount of energy which comes to the Earth from the Sun is vast. However, since almost all of it is distributed over the entire surface of the globe, the amount per unit of area is small. That is, one must say that it is a diluted energy. I once expressed this by saying that "solar energy is the 'low-grade ore' of energy" [1].

About half of the solar energy which comes to the Earth is lost by scattering and absorption by the atmosphere or the clouds. Nevertheless, the remaining energy, amounting to about 6×10^{20} kcal, reaches the Earth's surface every year. Only about /660 1/100,000 of this is converted into potential energy for precipitation or the growing of animal and plant life and is finally utilized by man as yields from agriculture, forestry, or fisheries or as hydroelectricity.

Humanity uses coal, petroleum, and natural gas as its so-called fossil fuels. However, there is a theory that even these are accumulations of solar energy of the past. However, here let us consider them separately. The annual consumption of fossil fuels for the year 1970 is estimated as equalling about 7,300,000,000 tons of coal (the standard tonnage of coal having a calorific value of 7000 kcal per kg). The figure given above -- the total amount of solar energy coming to the Earth's surface -- amounts to more than 10,000 times this number.

Let us now take our leave of these highly encouraging figures and take a look at the discouraging figures. They have to do with the density of solar energy. It is often said that the energy of sunlight amounts to about 1 kW per m^2. Hearing this, one would think that quite a lot of energy comes from the Sun. However, one must not forget that this figure applies to a plane

Nevertheless, the transition between the old and the new is the rule everywhere in the world, and I have no reason for melancholy over this. The world expects great things of solar energy. However, what is the current situation in solar energy research? Will it actually be possible for solar energy to meet the world's expectations and to become the savior of mankind in the energy crisis?

When such thoughts arise in one's breast, the larger is the conference, the more it seems to look like a sort of festival. The bright sun shining brilliantly outside the conference hall even began to look somehow pitiable. The most memorable impressions I retained from this conference were the following. First, the slogan "Switch on the sun" was written in English in thick letters on the bag of a young participant, evidently an America. Second, I remember the words reportedly spoken by the American engineer, Mr. Hottel, a famous researcher of long standing, to a Japanese participant. He said: "Utilization of solar energy is still at the stage of mere talk."

Difficulties of Utilizing Solar Energy

Especially today, when there is heightened interest in the utilization of solar energy, I think it is necessary for the general public to realize how difficult it is to utilize solar energy. In this way it will be possible to minimize misdirected or facile discussion.

The difficulties of utilizing solar energy are essential difficulties coming from the properties of solar energy itself. I classify them in terms of the following three items [4]: (1) high dilution, (2) intermittent nature, and (3) high entropy. In the following, let us describe each of these in some detail.

would like to make efforts hoping to be able to hold a conference in Japan, at least in 1979.

At any rate, it is certain that the Paris conference was the biggest international conference on solar energy ever held thus far. Public interest was higher than ever before, and it was reported in the newspapers and elsewhere. No doubt, this is because the end has come in sight for fossil fuels and because new appreciation has come to be given to solar energy as a "clean" energy which will not cause environmental pollution.

For the writer, who has been continuing research in this area, although on a very modest scale, for more than 20 years, it is truly gratifying that so many people should be interested in solar energy and that such a magnificent conference should be held about it. Some 15 years ago, in my book <u>Taiyō enerugii</u> [Solar Energy] [3], I introduced the foreign and domestic research which had been done at that time and attempted to arouse general interest in the subject. At that time, however, most people were more interested in the utilization of nuclear energy, and the reponse evoked was not a very large one. Now one may say that the situation has changed completely.

However, my mood was not a very cheerful one during the Paris conference. Probably this was partly because there were very few epoch-making papers, as I mentioned before. Partly this was also because the pioneers, who have been continuing their research in this field for many years, have gradually been disappearing. Professor Daniels of the United States, who was universally respected by solar men all over the world, is no longer, and one cannot see his slight body or his gentle smile. Madame Telkes, the Hungarian-born American, also did not come to this conference. I was extremely sad at hearing that Dr. Khanna of India, who was my closest friend, died shortly after the Melbourne conference.

8 km, and the power generated by them would be transmitted to the earth by masers. Since the project had already been widely advertised in newspapers and periodicals [1], there were few questions, and the report seemed to have little impact. On the contrary, more interest apparently was aroused by a plan being considered by Soviet scholars for using solar batteries to generate electricity. Their idea is to use numerous solar batteries on the Earth to generate power on the scale of several hundred to several thousand kilowatts. Since this was the first time that we had heard of this project, it aroused considerable interest. In particular, the use of lenses to condense the sunlight 6-10 times before admitting it to the solar batteries was close to the idea which I had announced 12 years before at the Rome international conference (sponsored by the United Nations) on new forms of energy (solar energy, geothermal energy, wind power) [2], and it was an idea of which I could heartily approve.

Actually, this was the first time that I had attended such a conference for 12 years, since the Rome conference. However, international conferences on solar energy have been held almost annually somewhere in the world ever since the conference held in 1955 in Arizona, U.S.A. The year before last, a conference was held in Melbourne, Australia, and one was held last year in Washington, U.S.A. I understand (according to Mr. Tetsuo Noguchi of the Government Industrial Research Institute, Nagoya) that at the ISES convention, which was held concurrently with part of this Paris conference, it was proposed that the conferences should be held every other year, since annual conferences are too frequent. Thus, a tentative proposal was made to hold one in the United States in 1975 and another one in India in 1977. Since a conference has never been held in Japan thus far, there apparently were many foreign researchers who desired to hold a conference in Japan once. The present situation in this country is somewhat embarrassing for us Japanese solar energy researchers, and we

The reports presented at the conference were reprinted exactly by offset and copies were distributed to the participants. However, the printing for the section on photoelectric effects was not in time, and we were informed that the reprints would be sent to the participants in the autumn. At the present time there are no plans to publish separately a collection of the papers presented at the conference.

The list of participants which we were given at the conference showed the number of participants from each country (excluding their companions). The local participants from France were, indeed, the most numerous, amounting to 252 persons, or about one-third of the total number. The next most numerous delegation was from the United States, with 83 persons. The United States always sends large numbers of delegates to conferences of this type, but there were especially many Americans at this particular conference, probably because it had been decided, in line with the Nixon Message, to make a full-fledged effort to take up solar energy research. The other countries were England, with 34 participants, Germany, with 30, Italy, with 18, and Belgium, with 15. It may be only natural that large numbers should be coming from the adjacent countries. Japan, Switzerland, and Canada each sent 14, and 13 came from Australia. I will omit the numbers from the other countries, although the total number of participants from the developing countries in Africa amounted to a considerable number. They all spoke French well and played quite an active role.

Next, as for the all-important question of the contents, unfortunately, there was nothing at this conference which made a very lasting impression. A specialist from ESSO made a report concerning the American NASA (National Aeronautics and Space /659 Administration) project for generating 10,000,000 kW of electric power. This project would involve assembling rows of solar batteries lengthwise and crosswise in space for distances of

France). While this contributed to making the conference a fluorishing one, it also apparently complicated the running of the conference. Since the seminar dealt with a subject which is not my specialty, I did not attend it, and therefore will not mention it here. Since a considerable number of persons in the fields of biology and agriculture attended it from Japan, no doubt they will report about the seminar somewhere.

Here let me confine myself to the conference itself. The conference was divided up into the following three sections, each one of which was further subdivided into a number of subsections (the numbers of the subsections are listed below). The conferences took place simultaneously, using almost all of the eight or so conference chambers at the UNESCO headquarters.

The sun, energy, and dwellings	13
Photoelectric effects and their applications	8
The sun and biology	9

The subsections which I attended were mostly those connected with the first section, "The sun, energy, and dwellings." For this reason, it was quite impossible to obtain a grasp of the whole. The original schedule before the conference was to divide it up into three main sections: "The sun and dwellings," "The sun and energy," and "The sun and biology." However, it was found that there were many papers connected with solar batteries, and also that many of the topics embraced both the dwelling and energy, such as those dealing with the question of heating. For these reasons, the organization of the conference was evidently changed.

The papers delivered at each of the subsections were summarized by a reporter and reported. After the report by the reporter, each author was given several minutes (the length of the time was different in the different sections) in which to make comments and to answer questions.

UTILIZATION OF SOLAR ENERGY

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About the Paris Conference /658*

There was a spell of intense heat in Paris at the beginning of July. The air-conditioning in the conference hall could not be said to be functioning at all well. The attendance of the conference was probably more than 800 participants, and about 350 papers were presented. The conference might well have been called a "highly successful" one.

From July 2 to 6 of this year, at the UNESCO headquarters in Paris, there was held an international conference concerning the utilization of solar energy under the title of "The sun in the service of mankind." The conference was jointly sponsored by three organizations: the International Solar Energy Society (ISES), the Mediterranean Corporation for Solar Energy (Corporation Méditerranéenne pour l'Energie Solaire, COMPLES), and the French Association for Study and Development of Applications for Solar Energy (Association Francaise pour l'Étude et le Développement des Applications de l'Energie Solaire, AFEDES). The conference was backed up by UNESCO and received financial assistance from about 10 other organizations.

In parallel with this conference, there was held another seminar on "Research methods for biometeorological environment of man" jointly sponsored by the French Office of Bioclimatological Studies (Office Francais de Recherches de Bioclimatologie, OFRB) and the French Meteorological Society (Société Météorologique de

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16. Abstract

The author gives his impressions of the international conference on "The sun in the service of mankind," held in Paris in July 1973. He outlines the difficulties of utilizing solar energy in terms of three basic properties: high dilution, intermittent nature, and high entropy. The current state and future prospects of utilization of solar energy in various forms are discussed. Throughout the article the author emphasizes his cautious outlook, somewhat tinged with pessimism, on the prospects for utilization of solar energy.

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